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(54) Identification system reader with multiplexed antennas

(57) An electronic system (8) is disclosed herein. The system includes circuitry (10) for processing a signal and a plurality of antennas (12a-12b). A plurality of switches (22a-22b) are also included. Each of the switches (22a-22b) is coupled between the processing circuitry (10) and a corresponding one of the antennas (12a-12b). Each of the switches (22a-22b) includes first

and second power MOSFETs where the source of the first MOSFET is coupled to the source of the second MOSFET. The system (8) further includes circuitry (28) for selecting of one of the plurality of switches (22a-22b) to be on.

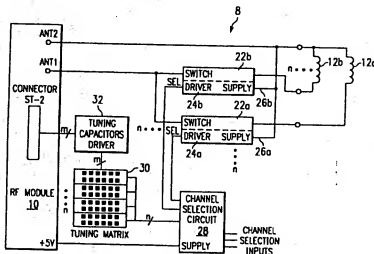


FIG. 2

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

The following co-assigned patents are hereby incorporated herein by reference:

Patent No.	Filing Date	Issue Date
5,053,774	02/13/91	10/01/91
5,450,088	11/25/92	09/12/95

FIELD OF THE INVENTION

This invention generally relates to identification systems and more specifically to an identification system reader with multiplexed antennas.

BACKGROUND OF THE INVENTION

There is a great need for devices or apparatuses which make it possible to identify or detect objects in a contactless manner and over a certain distance. An additional desire exists to be able to change the data stored in, or operating characteristics of, such devices or apparatuses (i.e. "program" the devices or apparatuses).

It is, for example, desirable to request contactless and over a certain distance identifications which are uniquely assigned to an object and which are stored in the device or apparatus so that, for example, the object may be identified. A determination may also be made as to whether or not a particular object exists within a given reading range. This concept can be used in a number of applications including security identification (e.g., security badges), inventory control, waste management, vehicle identification, and many others.

One such identification system is disclosed in U.S. Patent 5,053,774 (774) issued on October 1, 1991 to Schuermann et al. In that arrangement, the transponder (or responder) unit includes an energy accumulator which stores the energy contained in an RF interrogation pulse, which is transmitted from a reader (or interrogator). The transponder includes circuitry which senses the termination of the reception of the RF interrogation pulse and the presence of a predetermined energy amount in the energy accumulator. The circuitry triggers the excitation of an RF carrier wave generator operating with the frequency contained in the RF interrogation pulse. A signal generated by the RF carrier wave generator can then be retransmitted back to the reader thereby conveying information stored within the transponder.

In some applications the reading repetition rate of a transponder will be slow and it is desirable to couple a number of reading antennas to a single RF reader module. Therefore, there is presently a need for an identification reader with multiplexed antennas.

SUMMARY OF THE INVENTION

An electronic system is disclosed herein. The system includes circuitry for processing a signal and a plurality of antennas. A plurality of switches are also included. Each of the switches is coupled between the processing circuitry and a corresponding one of the antennas. Each of the switches includes first and second power MOSFETs where the source of the first MOSFET is coupled to the source of the second MOSFET. The system further includes circuitry for selecting one of the plurality of switches to be on.

In one embodiment, a novel switch/driver circuit is used to selectively couple a first node to a second node, e.g., to couple an antenna to a processing circuit. In this embodiment, a first power MOSFET with its drain coupled to the first node and a second power MOSFET transistor with its drain coupled to the second node comprise the switch. The source of the second MOSFET is coupled to the source of the first MOSFET, i.e., the MOSFETs are coupled antiseriably. A bipolar transistor has a base coupled to the gates of the first and second MOSFETs. A first diode is coupled to a high voltage node and a zener diode is coupled between the first diode and the emitter of the bipolar transistor. The circuit also includes a resistor coupled between the collector of the bipolar transistor and the first diode. In this circuit, a select signal is provided to the switch/driver circuit such that the switch/driver circuit is galvanically isolated from the select circuit.

In yet another embodiment, the present invention is utilized to constitute a reader for an identification system. This embodiment includes interrogator processing circuitry which has first and second antenna nodes. A number of antennas are coupled to one of the antenna nodes. A switch is associated with each one of the antennas between the antenna and the interrogator processing circuitry. Each switch is driven by a driver circuit. Each driver circuit includes a supply node which is coupled to the second antenna node of the interrogator processing circuitry. Channel selection circuitry is provided to generate a select signal for each one of the driver circuits. The channel selection circuit is galvanically isolated from each of the driver circuits.

The antenna multiplexer of the present invention has a number of advantages. First, the antenna multiplexed used with the present invention can be the same as the standard antenna used with prior art systems. In effect, the antenna system can support receive as well as transmit functions to be multiplexed between the different antennas. This feature provides a significant advantage by multiplexing the transmit and receive

functions as opposed to a receive-only antenna multiplexers.

Also, since standard antennas can be used, there is no change in the basic reading characteristic when multiplexing several antennas to a single interrogator. This is not the case when multiplexing special receive-only antennas to an interrogator.

The transmit antenna multiplexer can also be implemented very easily since it is not necessary to change anything inside the interrogator. The transmit antenna multiplexer can just be plugged between the antennas and the interrogation circuit.

In addition, the number of multiplexed antennas can be expanded very easily and the number of channels are unlimited. For one additional channel only the driver/switch unit and one tuning matrix block (i.e., set of jumpers) have to be added. (The channel selection circuit must be expanded only if all selection lines are already used up.) The tuning capacitors drive unit is unaffected by the number of multiplexed antennas.

BRIEF DESCRIPTION OF THE DRAWINGS

The above features of the present invention will be more clearly understood from consideration of the following descriptions in connection with accompanying drawings in which:

Figure 1 is a block diagram of a known reader and antenna;

Figure 2 is a block diagram of a reader with multiplexed antennas;

Figure 3 is a block diagram of a first embodiment impedance tuning circuit;

Figure 4 is a block diagram of a second embodiment impedance tuning circuit;

Figure 5 is a schematic diagram of a preferred embodiment switch and driver circuit;

Figure 6 is a cross sectional view of a power MOSFET which can be used within the switch circuit of Figure 5; and

Figures 7A and 7B are a schematic diagram of a specific embodiment reader circuit.

Corresponding numerals and symbols in the different figures refer to corresponding parts unless otherwise indicated.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The making and use of various embodiments are discussed below in detail. However, it should be appreciated that the present invention provides many applicable inventive concepts which can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use the invention, and do not limit the scope of the invention.

The following description of the present invention begins with a short description of a prior art reader described with respect to Figure 1. An improved reader which includes a number of antennas multiplexed to a single reader circuit will then be described with respect to Figure 2. A detailed view of a preferred embodiment tuning circuit and switch/driver circuit will then be described. Finally, a specific embodiment circuit is illustrated in Figures 7A and 7B.

Figure 1 illustrates a known system for coupling an identification reader 10 to an antenna 12. In the preferred embodiment, the reader circuit 10 may comprise a reader such as the one used in a TIRIS™ system manufactured by the assignee of this invention. An example of circuitry which may be used in reader circuit 10 is described in U.S. Patent No. 5,053,774 issued October 1, 1991. For the sake of brevity, this description will not be repeated herein but instead is incorporated by reference.

An antenna transformer 14 couples the reader 10 to the antenna 12. The transformer 14 can couple energy from a transmitter within reader 10 to antenna 12 and also from antenna 12 to a receiver within the reader 10. In other embodiments, the antenna 12 could be used to only transmit or only receive.

Capacitors 16a-16d are provided to tune the circuit so that only the desired frequency energy will be transmitted and/or received. Accordingly, the capacitors 16a-16d and antenna coil 12 serve as a resonant circuit. The four capacitors 16a-16d have been included because often one capacitor will be unable to withstand the high voltage and current at the antenna resonator. The parallel and serial connection technique illustrated reduces the current and voltage load on the capacitors 16a-16d. It should be understood, however, that any number of capacitors (i.e., one or more) can be used to serve this function.

Also illustrated in Figure 1 is tuning capacitor 18. The tuning capacitor 18 preferably comprises a variable capacitor which can be adjusted to compensate for variations in the impedance of the resonant circuit. In the preferred embodiment, the tuning capacitor 18 comprises a plurality of binary weighted capacitors 20a-20n coupled in parallel. Each of the capacitors 20a-20n has an associated switch 21a-21n which can be used to selectively include associated the capacitor 20a-20n in the circuit. As is well known, six binary weighted capacitors will provide 64 (i.e., 2^6) possible capacitance values.

In some applications, it is desirable to include a number of antennas 12a-12n with a single reader 10 as shown in Figure 2. For example, if the reading repetition rate of a transponder (not shown, see U.S. Patent No. 5,053,774 for a description of transponders which may be used with the present invention) is slow, a number of antennas 12a-12n can be connected to a single reader 10. The present invention discloses a multiplexer circuit which can accomplish this goal.

System costs can be reduced by using a single reader circuit 10 with several antennas 12. There is no inherent limitation on the number of antennas connected to the multiplexer circuit. The multiplexer circuit herein is especially usable with a RF module with a transmitter power stage and antenna circuit as described in U.S. Patent No. 5,053,774. But nevertheless, the concept of the multiplexer circuit can certainly be used with different RF modules which include other transmitter power stages and antenna circuits.

Figure 2 illustrates a preferred embodiment identification reader 8 which includes multiplexed antennas 12a and 12b. The circuit of Figure 2 includes only two antennas 12a and 12b for the sake of simplicity, but it should be understood that any number of antennas can be used.

The embodiment of Figure 2 includes interrogator processing circuitry 10. As mentioned above, the circuitry 10 may include the reader circuitry disclosed in U.S. Patent No. 5,053,774 or the circuitry disclosed in U.S. Patent No. 5,450,088. The circuitry 10 further includes first and second antenna nodes, labeled ANT1 and ANT2 in Figure 2. While interrogator processing circuitry 10 is labeled "RF Module" in this figure, other frequency circuits may also be utilized. Nothing in the present invention limits the circuit to RF frequencies.

In this embodiment, both the first and second antennas 12a and 12b are coupled directly to the second antenna node ANT2. The other terminals of the antennas 12a and 12b are coupled to the first antenna node ANT1 through switches 22a and 22b, respectively.

Comparing Figure 2 with Figure 1, it is noted that the transformer 14 and resonant capacitors 16a-16d in Figure 1 are implemented within interrogator processing circuitry 10 in Figure 2. However, this feature is not critical to the present invention. In other words, the transformer 14 and/or the capacitors 16a-16d can be implemented on-chip within the interrogator processing circuitry 10 as illustrated in Figure 2 or can be implemented externally as illustrated in Figure 1.

Driver circuits 24a and 24b are also included in the reader circuit 8 in Figure 2. Each driver circuit 24 is coupled so as to drive a corresponding one of the switches 22. In the preferred embodiment, each driver circuit 24 includes a supply node 26 which is coupled to the second antenna node ANT2. The preferred embodiment driver/switch circuit 24 and 22 is described in greater detail hereinbelow with reference to Figure 5.

During operation, only one of the antennas 12a-12b will be coupled to interrogator processing circuitry 10. Channel selection circuitry 28 is included to provide a select signal SEL to each of the driver/switch circuits 24 and 22. The channel selection circuitry 28 determines which antenna 12 is active, that is, connected to the interrogator processing circuitry 10. The select signal may generally comprise a digital signal which is utilized to turn the corresponding driver/switch circuit 24 and 22 either "on" (i.e., conducting) or "off" (i.e., non-conducting).

While illustrated external to the interrogator processing circuitry 10, it should be understood that the channel selection circuitry 28 may be internal as well. In the preferred embodiment the channel selection circuit 28 comprises a decoder but other circuitry can be used. Any circuit which receives an input and generates one (or none) corresponding high (or low) voltage and the remaining low (or high) will suffice.

As discussed hereinabove with respect to prior art Figure 1, the resonant antenna circuit may need a tuning capacitor to ensure the proper frequency signals will be transmitted and received. With multiple antennas 12a-12b in Figure 2, the problem becomes worse. Because of the differences in manufacturing, each of the antennas 12a-12b will be a little different and therefore each require a different tuning capacitor value.

Figure 3 illustrates one tuning circuit for individually tuning each antenna 12. In this embodiment, a tuning capacitor 18a-18n is provided for each antenna 12. The channel selection circuit 28 then selects which one of the capacitors 18 will be coupled to the resonant circuit. While this technique provides individualized tuning for each antenna 12, it is cumbersome because of the large number of capacitors 18 required.

The tuning matrix 30 of Figure 2 provides a better technique for providing the desired tuning function. The channel selection circuit 28 controls the tuning matrix 30 and the tuning capacitors driver 32. In the preferred embodiment, the tuning matrix 30 contains an individual jumper arrangement for each antenna 12. The individual jumper arrangement is addressed by the channel selection circuit 28 and the tuning capacitors driver 32 operates the corresponding tuning capacitors inside the interrogator processing circuitry 10.

The preferred tuning circuitry is illustrated in more detail in Figure 4. A set of jumpers 34a and 34b is provided for each antenna 12a-12b. These jumpers 34a and 34b will be preprogrammed with the appropriate connections so that the proper tuning capacitance value can be obtained. By way of example, the first set of jumpers 34a is programmed so that the most significant bit (MSB) capacitor 20a and the least significant bit (LSB) capacitor 20d will be selected when the first antenna 12a is selected. As another example, the second set of jumpers 34b is programmed so that the two least significant bit capacitors 20c and 20d will be selected when the second antenna 12b is selected.

To understand the operation of the tuning circuit, assume the channel selection circuit 28 selects channel 1. In that case, the line labeled CH1 in Figure 4 is high and the line labeled CH2 in Figure 4 is low. Because the MSB and LSB jumpers are connected, the high voltage on line CH1 will be coupled to switch transistors 21a and 21d through diodes 36a, and 36d, respectively. As a result, the switch transistors 21a and 21d will be conductive and the corresponding capacitors 20a and 20d will be coupled to the resonant circuit.

During this operation, the capacitors 20b and 20c will not be coupled since the corresponding switch tran-

sistors 21b and 21c will be non-conductive. In addition, the second set of jumpers 34b will be isolated by reverse biased, and therefore non-conducting, diodes 36b.

It is noted that the tuning capacitors 20a-20d do not require the more complex driver/switch circuit 24 and 22 (Figure 5) which is preferred for the antennas. This is because there will be a different voltage across the capacitors 20a-20d. In the embodiment of Figure 4, the tuning capacitors 20a-20d are connected to the antenna resonator via MOSFETs 21a-21d. However, the tuning capacitor at a switched off MOSFET (e.g., capacitor 20b and 20c if the first channel CH1 is selected) is charged up with a DC voltage via the parasitic drain/source diode of this MOSFET (21b or 21c in the example). Thus a 'positive' DC voltage is charged onto this tuning capacitor. This leads to the fact that the voltage at the drain of the MOSFET no longer becomes negative and thus the parasitic diode is no longer conducting. So in this special case, the switch and driver circuit of Figure 5 are not necessary.

The preferred embodiment driver circuit 24 and switch circuit 22 will now be described in more detail with reference to Figure 5. The switch 22 comprises low-resistive and high-voltage power MOSFETs 40 and 42. The power MOSFETs 40 and 42 are coupled so that the source S of the first MOSFET 40 is coupled to the source S of the second MOSFET 42. This antiseri-connection is made to cancel out the parasitic diode (70 in Figure 6) which exists between the source S and drain D of the MOSFETs 40 and 42.

Figure 6, which has been included to help illustrate the existence of the parasitic diode 70, illustrates a cross-sectional view of an exemplary power MOSFET 40 or 42 to illustrate the parasitic diode 70. When the parasitic diode 70 is conducting, current flows from the source pin S to the drain pin D through the following regions: n+ source region 72, p channel region 74, n substrate 78 and n+ drain region 76. Therefore, the parasitic diode 70 is formed by the p channel region 74 and the n substrate 78. When the power MOSFET 40 or 42 is switched on, the p channel region 74 is transformed into an inverted region and thus the power MOSFET 40 or 42 is conducting.

Because this parasitic diode 70 cannot easily be avoided, one way to eliminate the conducting path (via the parasitic diode 70) is to include an additional device in series, e.g. another diode. In order to have a low resistive path when the MOSFET 40 is switched on, the second serial device is preferably another MOSFET 42. This device gives low on resistance. When connecting two MOSFETs 40 and 42 antiseri-ally, there is no longer a conducting path through both antiseri- MOSFETs (when switched off) because the parasitic diode 70 in one of the two MOSFETs 40 or 42 will always be biased off. In other words, for each polarity applied to both MOSFETs 40 and 42, there is always one of the parasitic diodes 70 blocking any parasitic current. Thus, no

parasitic current will flow from RF module 10 to antenna 12 (in Figure 5).

The power MOSFETs for the driver/switch circuit 24 and 22 can be selected according to the application. For high quality factor antennas, high quality MOSFETs should be used. For example, the resistance between source and drain when the transistor is conducting ($R_{DS, on}$) can be 0.05 Ohms or less. But for applications with antennas which have a low quality factor, MOSFETs with a higher $R_{DS, on}$ and low drain-source voltage can also be used.

The switch 22 is operated by driver circuit 24. Because the MOSFETs 40 and 42 are connected antiseri-ally, the source potential (at nodes S) is floating. Therefore, the driver circuit 24 must also be floating. As a result, the driver circuit 24 receives the select signal SELECT (from channel selection circuit 28, Figure 2) via an optocoupler 44. The optocoupler 44 comprises a light emitting diode 46 which turns on a transistor 48 when the SELECT signal is low. While illustrated with an optocoupler 44, any other input circuit which galvanically isolates the driver circuit 24 from the channel selection circuit 28 can be used.

The transistor 59 is included so that the optocoupler 44 is active (i.e., conducting light emitting diode 46 and transistor 48) only when the corresponding channel is active (i.e., corresponding switch circuit 22 is conducting). This element therefore reduces the current consumption of the whole circuit since there is only current flow through the optocoupler 44 of an active channel. As only one channel at a time is active in most applications, this reduction results in minimum current consumption of the driver circuit 24.

The driver circuit 24 is supplied from high RF voltage (e.g., several hundred volts peak-to-peak) of the antenna resonator ANT2 (see also Figure 2). The resistor 50 is provided to limit the current from the antenna resonator and thus avoids damping of the antenna resonator. Zener diode 54 is provided to limit the voltage at node 56. This voltage is limited so that it will not exceed the maximum allowed gate-source voltage of the MOSFETs 40 and 42 and the collector-emitter voltage of the driver transistor 59. The diode 52 rectifies the AC signal from antenna resonator node ANT2. Rectification is desired to store a DC voltage on capacitor 58. The voltage stored on capacitor 58 is used as gate drive voltage when the MOSFETs 40/42 are switched on.

Because there is no AC voltage coming from the antenna resonator node ANT2 when the transmitter is switched off, the MOSFETs 40 and 42 could not be turned on from an idle start point (i.e., when none of the antennas are connected and the antenna resonator node ANT2 has no voltage applied). Since the node ANT2 cannot be taken to a high voltage until at least one of the switches 22 is on, another technique is needed to store a DC voltage on capacitor 58.

Storing this DC voltage on capacitor 58 in an idle state can be done via resistor 60 and diode 62. The charge capacitor 58 is charged up from an external pos-

itive supply Vcc via the following elements: resistor 60, diode 62, the parasitic diode 70 of MOSFET 42 and the antenna terminal ANT1 (via the transformer to ground). Therefore the parasitic diode 70 of the MOSFET 42 is actively used in the idle state to have a DC path to ground to store a DC voltage on charge capacitor 58. The charge on capacitor 58 enables to switch on MOSFETs 40 and 42. The diode 62, as well as diode 52, are included to decouple the high RF voltage node ANT2 from the supply and node Vcc.

It is noted that to start the system from an idle state only one of the switches 22 needs to be enabled to conduct. In other words, the connection to supply node Vcc, resistor 60 and diode 62 may be eliminated from all but one of the drive circuits 24a-24n in the system. For example, if only the channel 1 drive circuit 24a includes the connection to the DC power supply, then the circuit would always be started by selecting channel 1. After the antenna resonator node ANT2 charges up, any of the other channels may be selected.

A more specific schematic diagram of an embodiment of the present invention is illustrated in the circuit of Figures 7A and 7B. The circuit of Figures 7A and 7B provides further details as to the specific configuration and some of the component values which can be used to implement the present invention. The circuit has been labeled with reference numerals which correspond to those used in the previously discussed figures. In this embodiment, inverters HC04 have been included and as a result the polarity of the diodes 36 has been reversed. It is of course understood that other specific designs could be utilized to implement the broad concepts described herein.

Claims

1. An electronic system comprising:

circuitry for processing a signal;
a plurality of antennas;
a plurality of switches wherein each of said switches is coupled between said circuitry for processing and a corresponding one of said antennas, each of said switches including first and second power MOSFETs each having a source, a gate and a drain, wherein the source of the first power MOSFET is coupled to the source of the second power MOSFET; and
select circuitry for selecting at most one of said plurality of switches to be on.

2. The system of claim 1 wherein said first and second power MOSFETs comprise n-channel power MOSFET transistors.

3. The system of claim 2 and further comprising a plurality of driver circuits, each of said driver circuit associated with one of said switches for driving said

switch, each said driver circuits coupled to said select circuitry.

4. The system of claim 3 wherein each of said driver circuits includes an optocoupler for receiving a select signal from said select circuitry.

5. The system of claim 4 wherein each of said driver circuits further includes:

a first resistor coupled to a high voltage node of an antenna resonator;
a rectifying circuit coupled to said first resistor;
a bipolar transistor for receiving said select signal from said optocoupler, said bipolar transistor having an emitter, a collector and a base, said base of said bipolar transistor coupled to said gates of each of said first and second power MOSFETs; and
a zener diode coupled between said rectifying circuit and said emitter of said bipolar transistor.

6. The system of Claim 5 wherein said rectifying circuit is a first diode.

7. The system of claim 6 and further comprising a plurality of tuning capacitors, said tuning capacitors selectively associated with each of said antennas.

8. The system of claim 7 wherein said tuning capacitors comprise binary weighted capacitors.

9. The system of Claim 8 wherein said drain of said first power MOSFET is coupled to a first node of said circuitry for processing and said drain of said drain of said second power MOSFET is coupled to a second node of said circuitry for processing through one of said antennas.

10. The system of Claim 9 wherein each of said driver circuits further include:

a zener diode coupled between said first diode and said emitter of said bipolar transistor;
a second resistor coupled between said collector of said bipolar transistor and said first diode; and
said optocoupler for coupling said select signal from said select circuitry to said driver circuit such that said driver circuit is galvanically isolated from said select circuitry.

11. The system of claim 10 wherein each of said driver circuits further includes a capacitor coupled in parallel with said zener diode.

12. The system of Claim 11 wherein each of said driver circuits further includes:

a third resistor coupled to a supply voltage node;

a second diode coupled between said third resistor and said capacitor; and

a fourth resistor coupled between said second diode and said base of said bipolar transistor. 5

13. The system of Claim 12 wherein each of said driver circuits is coupled to a power supply at said supply voltage node for supplying power to at least one of said driver circuits during a start-up phase. 10

14. The system of claim 13 further including:

at least one resonant capacitor with a first terminal coupled to said first node; 15

a plurality of tuning capacitors;

a tuning matrix, said tuning matrix including a plurality of sets of jumpers wherein each of said 20

sets of jumpers corresponds to one of said antennas, said tuning matrix for receiving a

tuning select signal from said select circuitry so that selective ones of said plurality of tuning

capacitors are coupled to said resonant capacitor. 25

15. The system of claim 14 wherein said at least one resonant capacitor comprises two resonant capacitors coupled in series, wherein said tuning capacitors are coupled between said two resonant capacitors. 30

16. The system of claim 14 wherein said tuning capacitors comprise a plurality of selectively coupled binary weighted capacitors. 35

17. An identification system including a reader in accordance with any of Claims 1-16. 40

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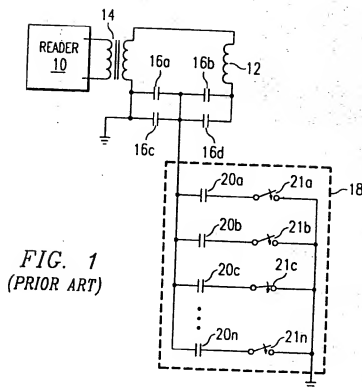


FIG. 1
(PRIOR ART)

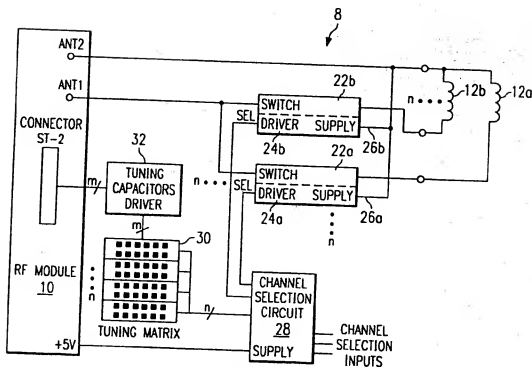


FIG. 2

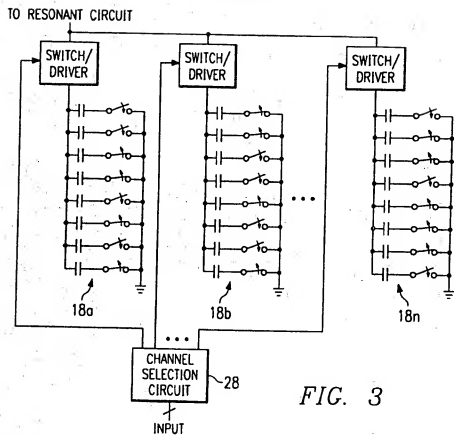


FIG. 3

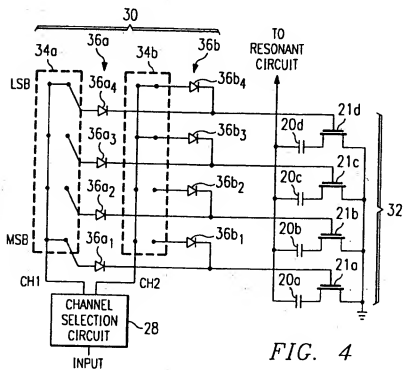


FIG. 4

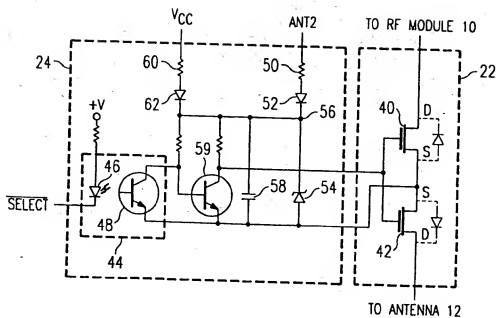


FIG. 5

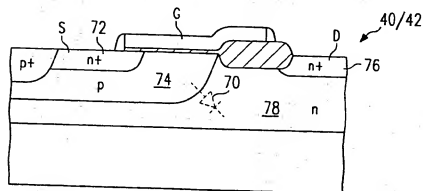


FIG. 6

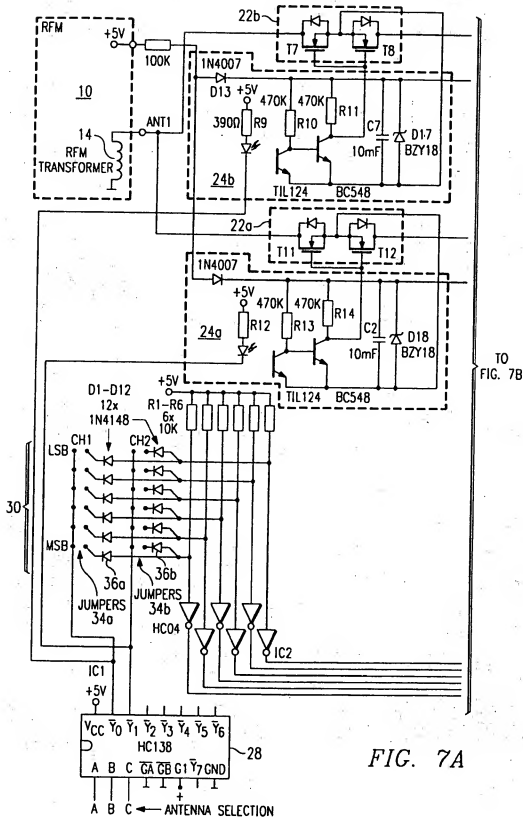


FIG. 7A

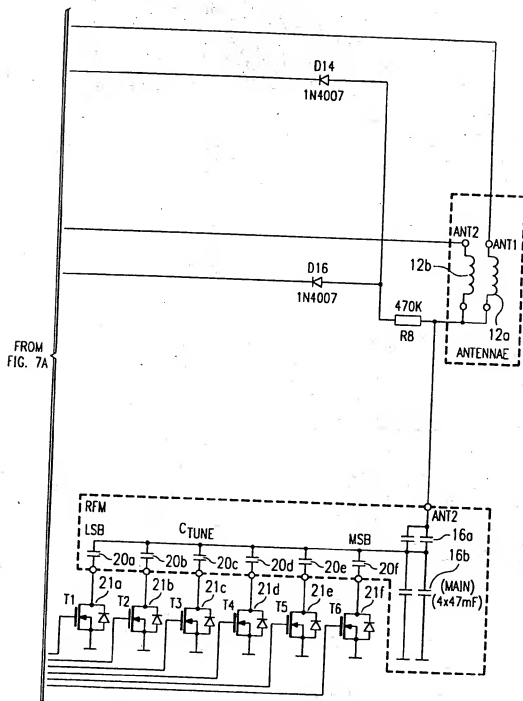


FIG. 7B